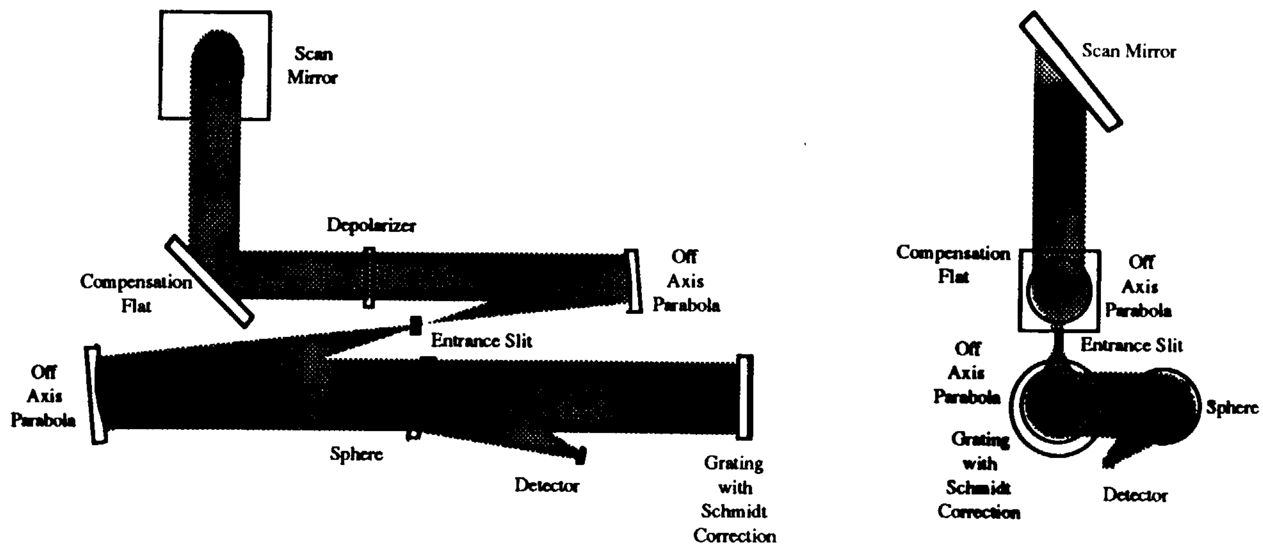
MODIS-T
Instrument Status Report



January 31 1990

Critical Science Requirements

	January 24, 1989	July 13, 1989
Spectral Range	400 to 1040 nm	400 to 880 nm
Bandwidth	10 nm FWHM (64 bands)	10 to 15 nm FWHM (32-48 bands)
IFOV	1.0 km at nadir	1.1 km at nadir
Linear Polarization	≤ 2% for bands < 700 nm ≤ 4% for bands > 700 nm over all tilt angles	≤ 2.3% over ±20° tilt
Signal to Noise	specification	specification
Dynamic Range	land	select land or ocean
Line of Sight Knowledge	known to ±29 arcseconds	known to ±60 arcseconds

General Status

o ***System Engineering*** - Subsystem requirements. Subsystem interfaces. Grounding philosophy.

o ***Optics*** - Basically the same design. Mount on a common optical plate. Rotated the entrance slit. Curved detector. Meet all optical requirements.

o ***Mechanical*** - Layed out present concept. NASTRAN anal is. Determined cold plate mounting. Aluminum optical baseplate.

o ***Mechanisms*** - Single speed scan. Tilt. Diffuser. Aperture wheel.

o ***Electronics*** - Fully redundant. No electronics on the optic plate. Six electronic boxes. Memory in C&DH. 12 bit linear A/D converter. Using cold plate. Harness defined. Preliminary reliability analysis.

o ***Thermal*** - Cold plate tradeoff study. Aluminum optical bench analysis. Thermal analysis.

o ***Calibration*** - Diffuser plate. Solar integrating sphere. Helium RF sources. No tungsten bulbs.

o ***Detector*** - 34 by 30 photodiode interline CCD. No charge transfer problems. Dual mode: Ocean or Land dynamic range. CCD width determined by throughput and S/N requirements. Fabricating 4 by 16 photodiode interline CCD. Designing flight-like 34 by 30 photodiode interline CCD.

o ***System Analysis*** - Completed S/N analysis and detector design inputs. Meet S/N requirments. Completed STOCS/ACOS analysis. Completed preliminary earth footprint analysis.

MODIS-T
OVERALL PRIORITIES

RELIABILITY AND LONGEVITY

INSTRUMENT CHARACTERIZATION AND CALIBRATION

RADIOMETRIC STABILITY

MODCHT\PHB1 FH 4/24/89

MODIS-T

TRADES CONSIDERED IN THE EXTENDED PHASE B STUDY

- LAND/OCEAN MODES
- OPTICS
- SCAN TECHNIQUE
- TILT METHOD
- DETECTORS
- PERFORMANCE
- CALIBRATION
- ELECTRONICS
- THERMAL DESIGN

MODIS/PHB7 FH 4/28/89

OPTICS TRADE

Baseline grating design modified and refined

Alternate prism design under investigation

Some advantages of the PRISM design

- No depolarizer required
- Excellent image quality

Some disadvantages of the PRISM design

- Variable pixel size required for constant 15 nm bandwidth
- low effective throughput due to narrow slit requirement

GRATING design remains the baseline

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SCAN TECHNIQUE TRADE

Variable speed and constant speed scan techniques studied.

CONSTANT SPEED scan technique selected

Advantages

Lower risk scan mechanism than variable speed
Less potential mechanical disturbances

Disadvantages

Lower scan efficiency
Larger buffer memory required (FIFO)

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TILT METHOD TRADE

Full optical bench tilt and scan mirror tilt options studied.

SCAN MIRROR TILT selected

<u>Advantages</u>

Less massive support structure for the optical bench
Easier to meet pointing knowledge requirements
Eases thermal design greatly

<u>Disadvantages</u>

Image rotation (similar to GOES NEXT)
Slightly higher polarization (about 0.1% higher)

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DETECTOR TRADE

Frame Transfer CCD and Photodiode Interline CCD devices studied.

PHOTODIODE INTERLINE CCD design selected

Advantages

No image smear (high speed shutter not needed)
Good charge transfer efficiency (lower clock rates)
High quantum efficiency
Relatively simple fabrication
Four phase clock

Disadvantages

Less dynamic range than the Frame Transfer CCD

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CALIBRATION TRADES

LINE SOURCES

Laser diodes and RF excited HE sources were considered

RF EXCITED HE sources selected

Advantages

Stable spectral lines
Multiple spectral lines (6)
Same sources that have been selected for some ISTP missions
No power converter required

BROADBAND SOURCES

Tungsten sources and the sun were considered

The SUN was selected

Advantages

No power converters required
Stable source
Good spectral radiance match to ocean radiance

Disadvantages

No radiometric calibration on the night side
Difficult to couple into the instrument aperture

\modcht\phbp11 FH 11/21/89

ELECTRONICS TRADES

12 BIT vs 14 BIT Analog to Digital Converter

12 BIT selected

Provides adequate signal to noise due to lower scene dynamic range
Lower power, smaller size, available

PACKAGING

Study to be conducted in 1990 to determine the optimum number of electronics boxes. Trade parameters include: cost, weight, EMI/EMC, testing, integration, maintenance, handling

POWER
Converter switching frequency - 20 to 30kHz vs 100 to 120KHz

20 to 30 kHz selected

Higher tolerance to radiation and single event upsets

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THERMAL/STRUCTURAL TRADES

ELECTRONICS THERMAL CONTROL

Passive radiators and the Eos
cold plate were considered

Eos COLD PLATE selected

Advantages

Minimum weight
No operational heaters required
for electronics boxes
Enhanced reliability due to
small temperature variations
of the electronics

Disadvantages

Difficult access to electronic
boxes (also a problem with the
other options)

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OPTICAL BENCH MATERIALS

Aluminum and Invar were
considered

ALUMINUM was selected

Very little power coupled in
the bench and thermal blankets
minimize thermal gradients

Lower weight, availability

Top Level Instrument Parameters

	First Phase B Study	Present
Weight	178 kg (*191.6 kg**)	148.8 kg
Power	105 watts	90 watts
Data Rate	16 Mbits/sec, 50% duty	3 Mbits/sec, continuous
±50° Tilt	tilt the entire instrument	tilt the scan mirror
Detector	64 X 64 CCD	34 X 30 photodiode/CCD interline
Major Mechanisms	scan mirror (two speed) tilt (entire instrument) diffuser (160 cm high) shutter (every 8.95 sec) shutter (every 4.04 msec) cover (seal the forebaffle)	scan mirror (single speed) tilt (scan mirror) diffuser (50 cm high) aperture wheel
Power Supplies	17 power supplies	7 power supplies (+2#)
	**with required memory and single band packets.*	*#RF sources packaged with power supplies.*

TOP LEVEL INSTRUMENT PARAMETERS
(Continued)

	First Phase B Study	Present
Swath	±45 degrees 64 km X 1500 km	±45 degrees 33 km X 1500 km
IFOV	1.42 mrad (1.0 km)	1.56 mrad (1.1 km)
Optics	Grating type imaging spectrometer f/3.1, 33.8 EPD	Grating type imagi spectrometer f/3.0, 34mm EPD
Detector integ. time	4.04 ms	1.14 ms ocean mod 0.3 ms land mode
Calibration	Full aperture	Full aperture

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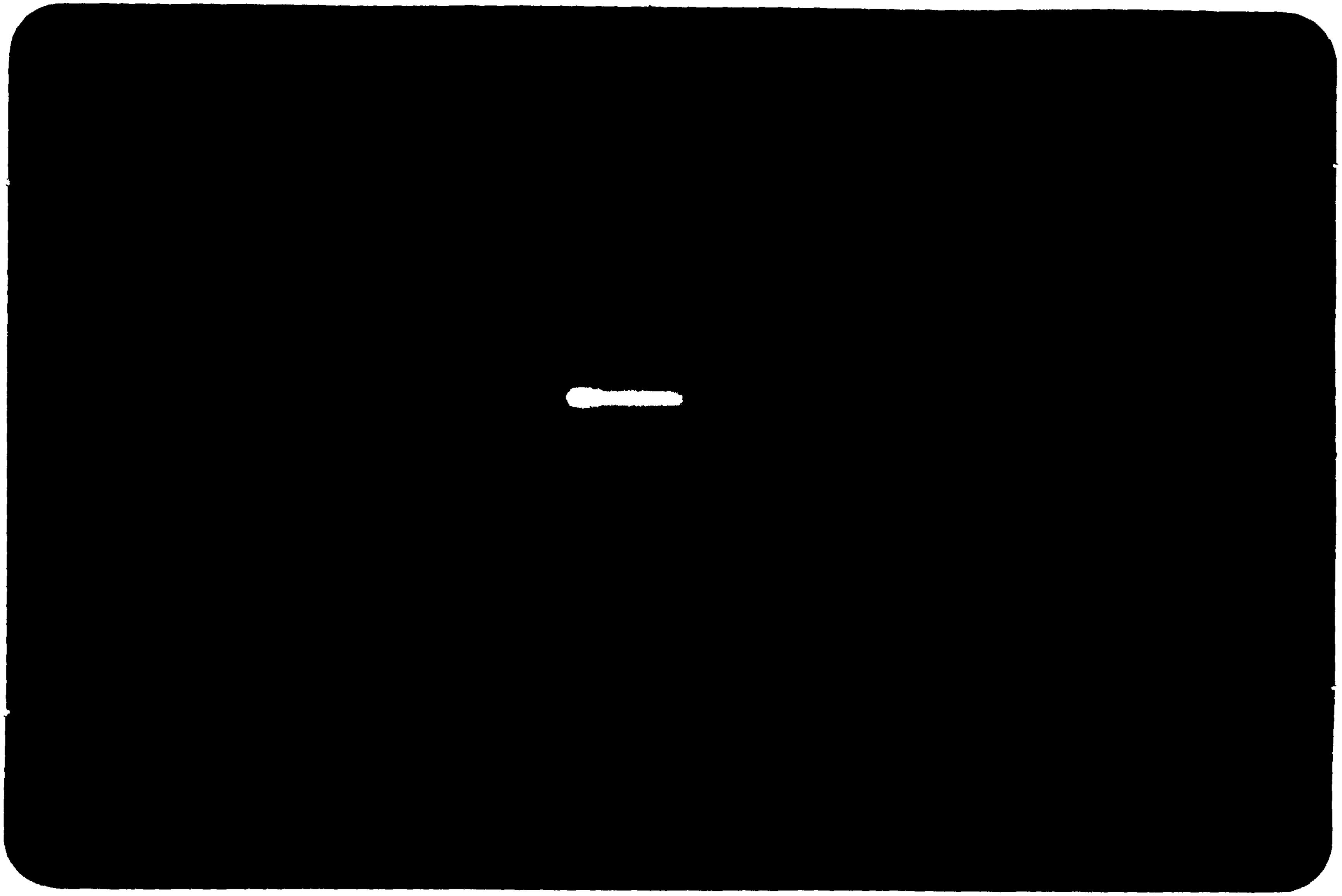
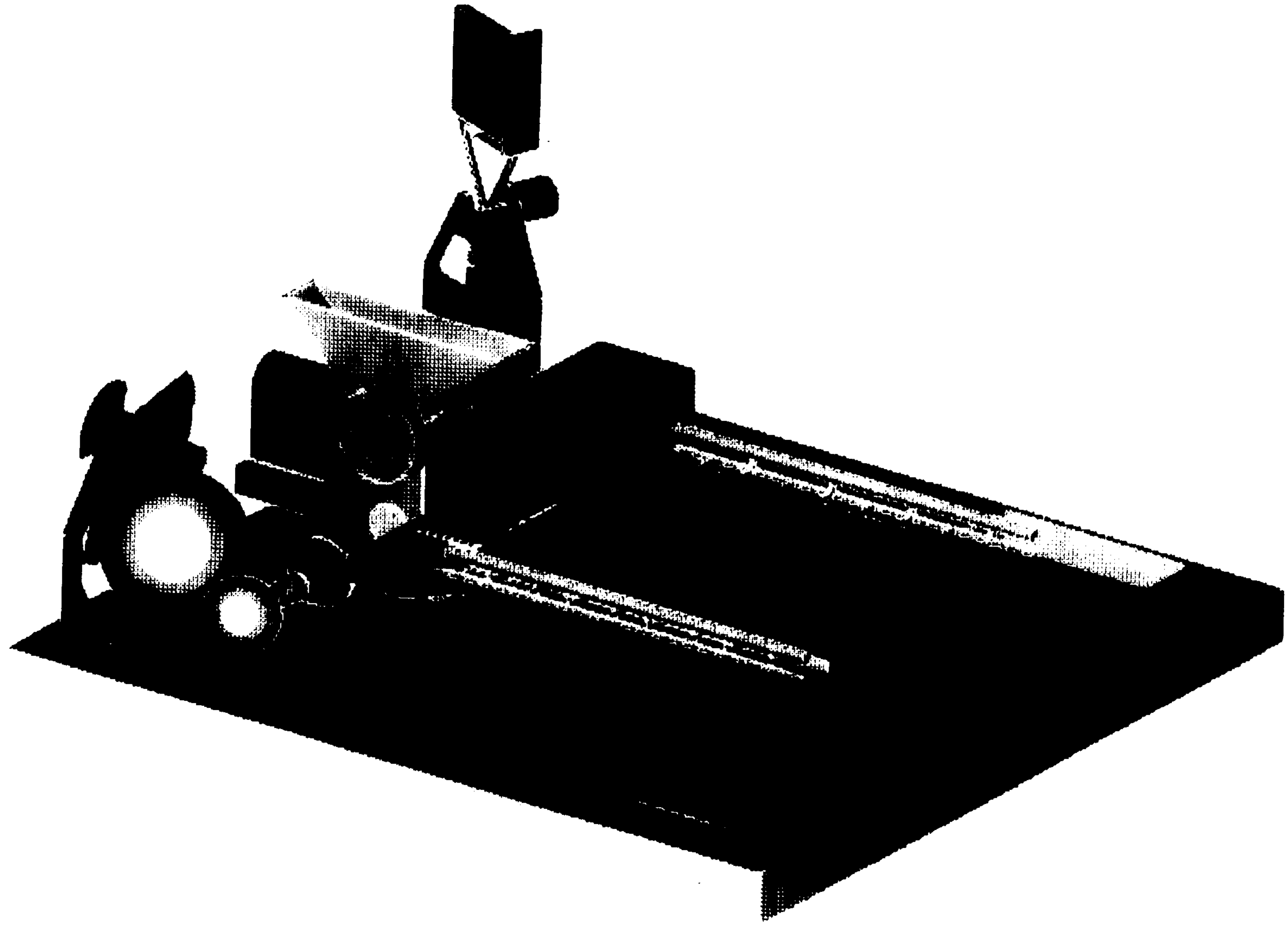
COMPUTER GRAPHIC FORMAT



NOTES



OPTICAL DESIGN

- Grating-Type Reflecting Schmidt Imaging Spectrometer
- 34 mm entrance aperture
- f/3.0 system
- Detector is curved in one dimension to reduce spatial distortion
- All aluminum except for the scan mirror
  the scan mirror will most likely be beryllium
- Components mount to a common optical baseplate
- Design meets all specifications

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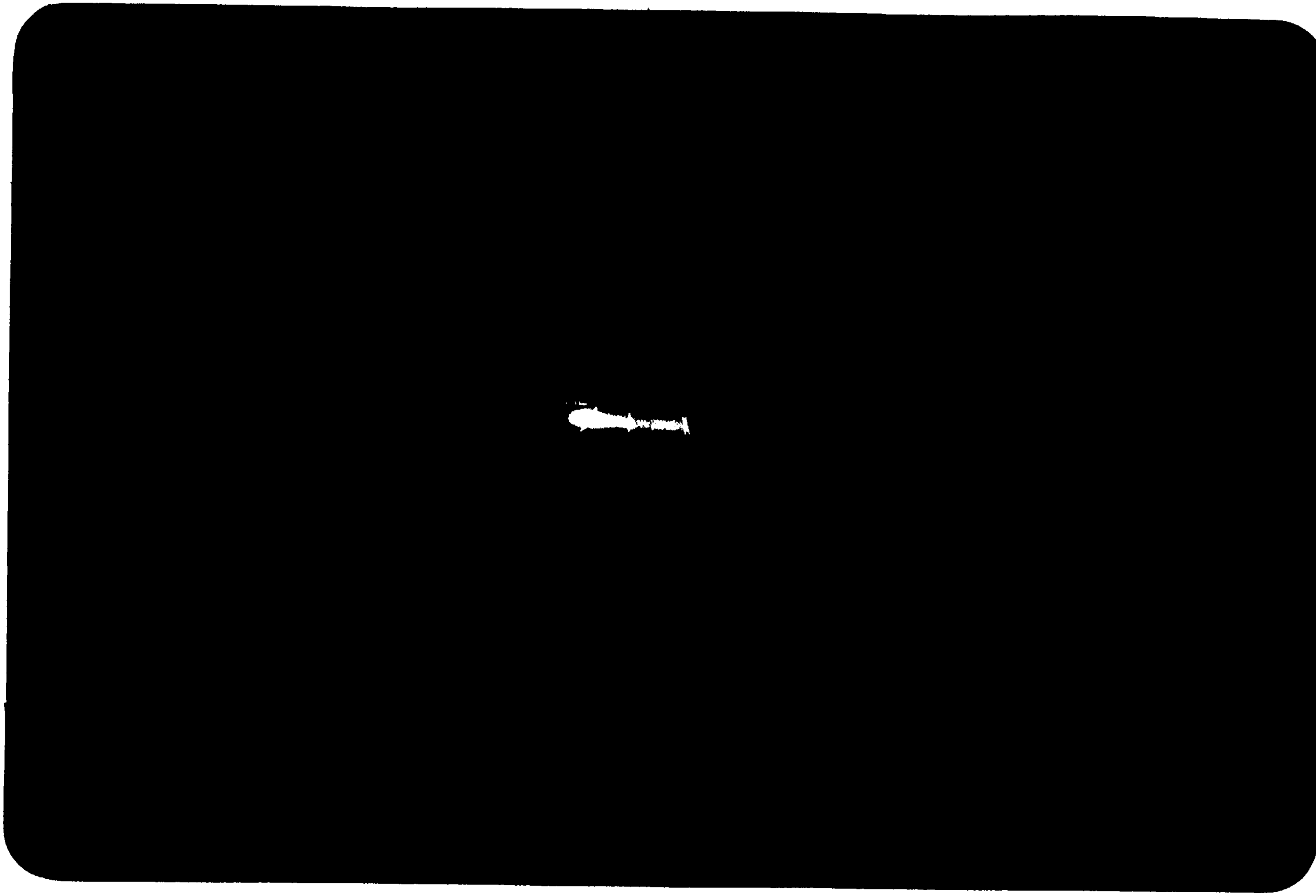

NOTES

MECHANISMS

- Scan - Continuously rotating single speed (6.6 rpm)
  Double sided scan mirror
- Tilt - Rotates the scan assembly about the center of the scan mirror. Direct drive used.
- Diffuser - Deploys the solar diffuser about 50 cm above the Eos plate. Can be viewed at a instrument tilt angle of -30 degrees.
- Aperture Wheel - Used with the solar integrating sphere. Provides 3 aperture settings and a closed position.

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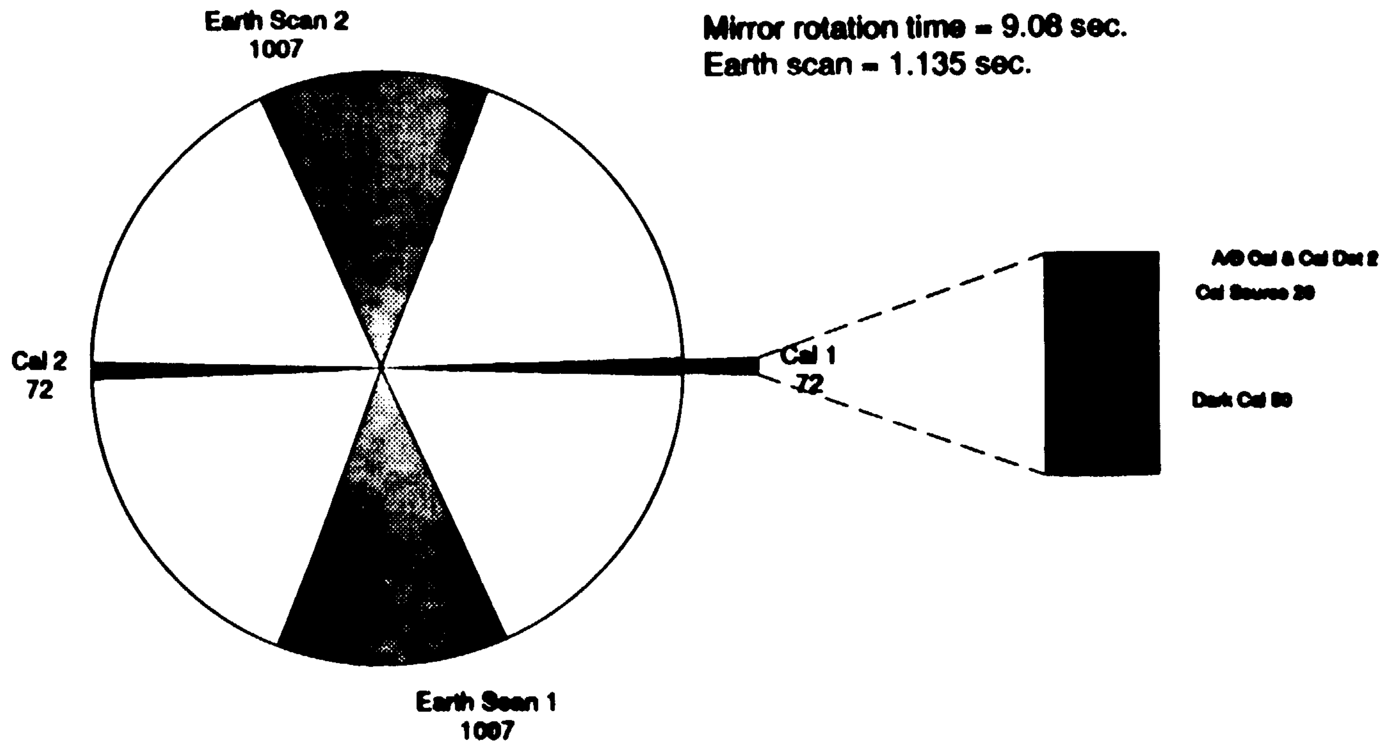
SCAN SEQUENCE

Mirror rotation time = 9.08 sec.
Earth scan = 1.135 sec.



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FLIGHT CALIBRATION

- Full aperture diffuser plate (two levels) used at the South Pole.
- Solar integrating sphere

  Can be used from the South Pole to the North Pole for instrument stability monitoring.

  Three flux levels

  Helium RF sources mounted to the integrating sphere provide 5 spectral lines for instrument spectral calibration.

  Can be viewed during the instrument backscan at tilt angles between -30 and +20 degrees.

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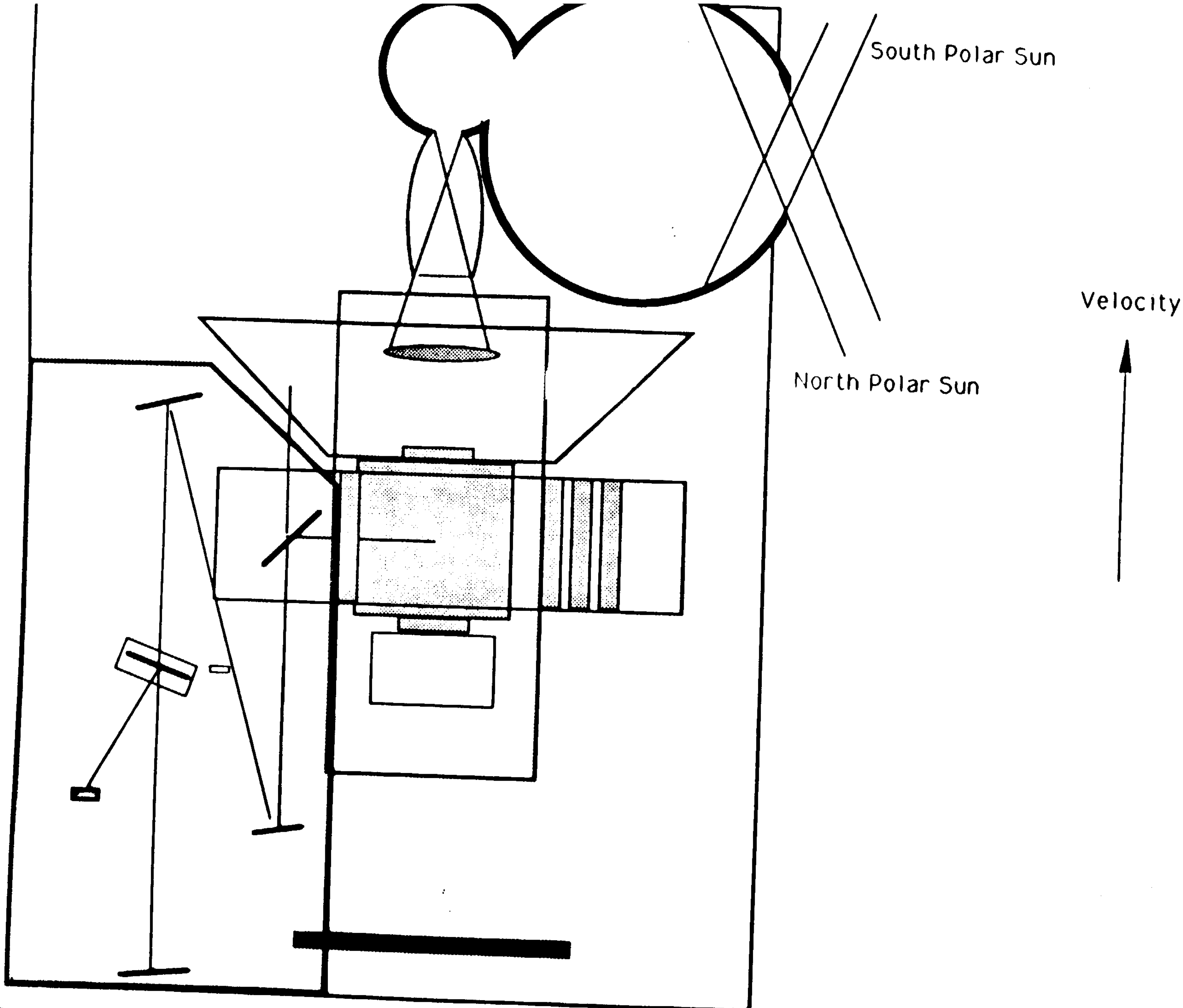
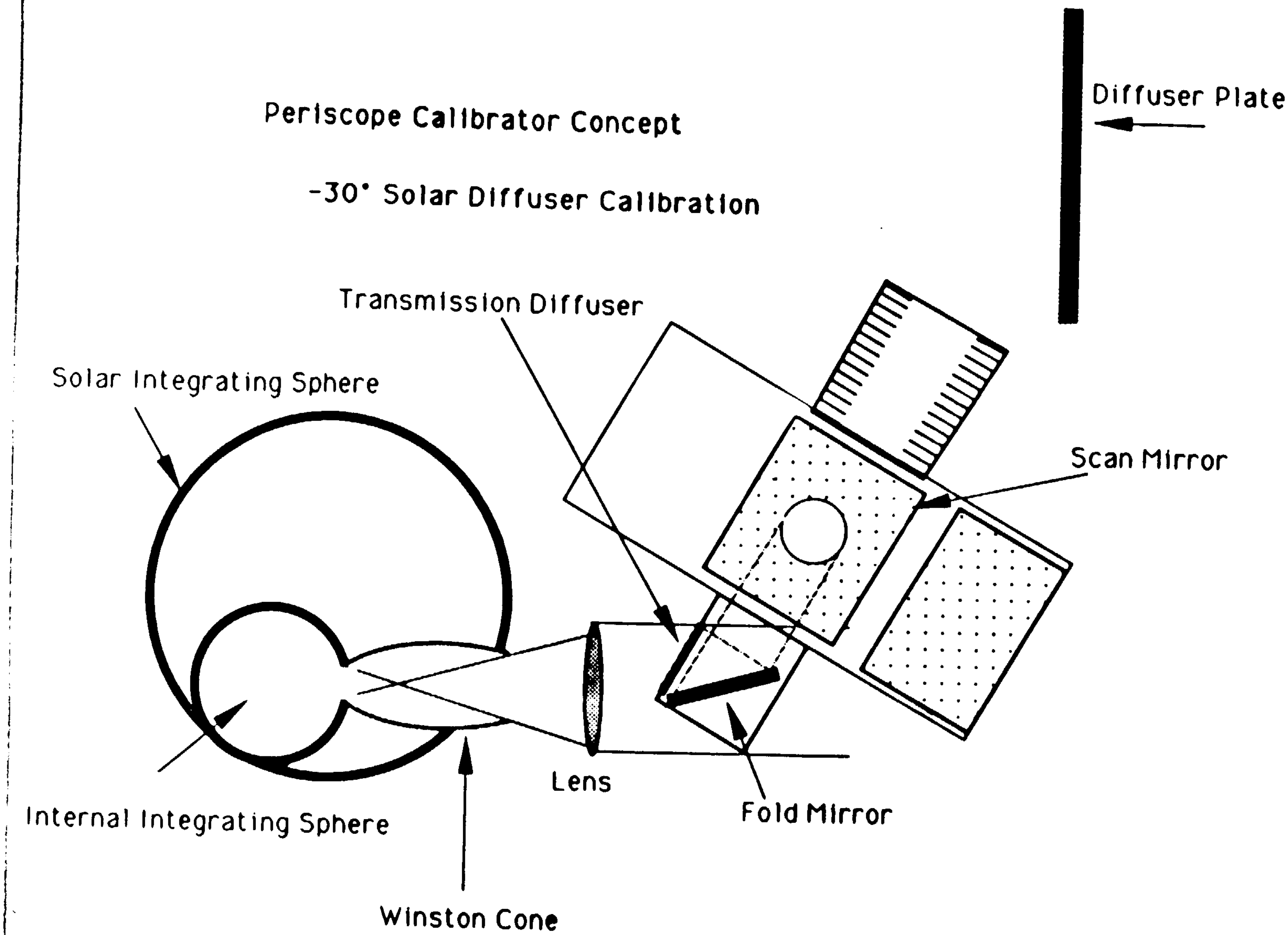

South Polar Sun
North Polar Sun
Velocity

Periscope Calibrator Concept

-30° Solar Diffuser Calibration



DETECTOR

- 34 X 30 photodiode interline CCD
- Two output ports (each with a redundant output)
- Pixel size of 220.5 μm (spectral) X 161.7 μm (spatial)
  Chip size of 7.5 mm X 10.2 mm
- CCD width of the detectors in each spectral channel is determined by the required charge handling capacity
- Dual operating mode - commandable to either land or ocean mode
  - 1.13 ms ocean integration time (100% of dwell time)
  - 0.30 ms land integration time
- Anti-blooming and drain structures implemented

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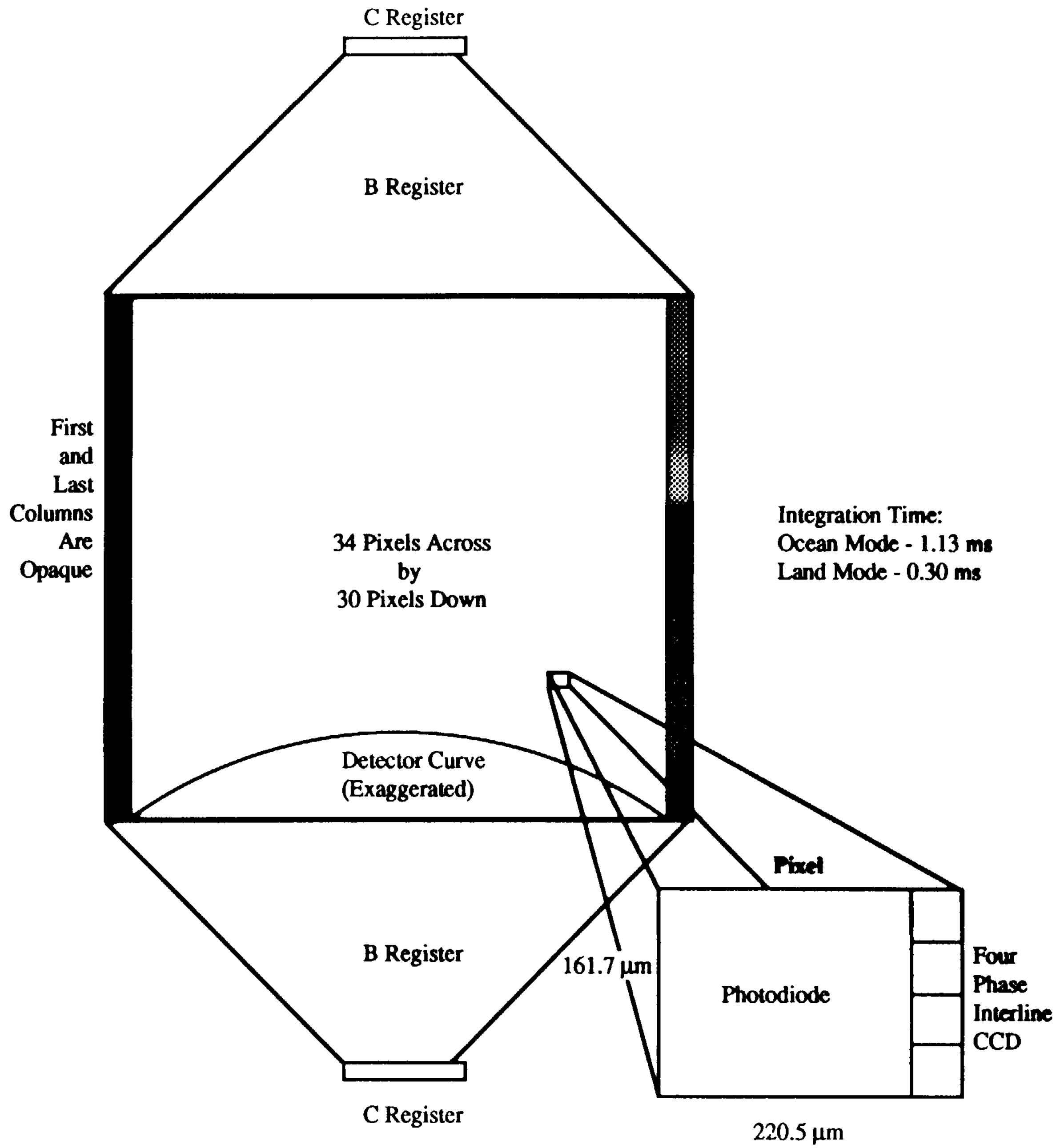
C Register
B Register
First and Last Columns Are Opaque
34 Pixels Across by 30 Pixels Down
Integration Time:
Ocean Mode - 1.13 ms
Land Mode - 0.30 ms
Detector Curve (Exaggerated)
Pixel
B Register
161.7 μm
Photodiode
Four Phase Interline CCD
C Register
220.5 μm

ELECTRONICS

- Array Signal Processing
  - Correlated Double Sampling of Det. Sig
  - 12 Bit Linear A to D
  - 3 level electronics reference
- Command and Data Handling
  - CMD, time/freq, ancillary data on LAN
  - High rate interface for image data
  - Ping-pong memory used for data buffer (30 Mbits)
- Redundancy
  - Fully Redundant on a Subsystem Level Except for the Detector
  - Cross Strapping in Selected Areas
- Power
  - Supply Voltage of 120 Volts DC
  - Secondary converters located at loads
  - 20 to 30 kHz switching frequency

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EMI/EMC RECOMMENDATIONS

- Keep all noise within each box
- Use isolation on signals between boxes
- Ground each converter secondary to chassis at one point
- Power via shielded twisted pair with shield chassis connection at source only
- Lo-Z, Wide bandwidth ground plane (DC - 1 MHz)
- Sync all convertors (4 total)
- Bundle shields to chassis ground at both ends

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ANALYSIS & PERFORMANCE

MTF
- Budget developed - includes effects of jitter
- Predicted performance meets specification

Geometric
- Pointing knowledge error budget developed
- STOCS analysis performed to determine thermo-optical sensitivities
- Preliminary thermal design and analysis of the optical bench completed. Thermal design driver is the requirement for a gradient through the optics plate of no more than 0.3 degrees C.
- Aluminum optics bench will meet the requirement

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ANALYSIS & PERFORMANCE
(Continued)

Stray Light - spec. has been eased but it is still tough

- Dark pixel in a field of LMAX most difficult
- Requires very clean optics, level 100 to 500

Polarization Sensitivity

- Meets spec with the use of a fold mirror and depolarizing element (not much margin)

Scene Dynamic Range

- Two commandable imaging modes; Land and Ocean
- Different integration time and gain for each mode

Fore/Aft Tilt - $\pm$20 deg. required, $\pm$50 deg. desired

- +67.5 deg.(lunar cal.), -50 deg. implemented
- Tilt angle not a driver

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ANALYSIS & PERFORMANCE
(Continued)

On-Board Calibration - Several sources provided to meet radiometric, spectral, and electronics cal requirements

Data Rate and Packetization - constant data rate and single band per packet required

- 30 Mbit ping-pong memory required
- Size, weight, reliability driver

Power - Current estimate of 90 watts orbital average is below the 100 watt requirement

Weight goal of 100 kg - Current estimate is 160 kg.

Reliability

- Initial reliability analysis completed
- C&DH buffer memory and the scan mechanism are reliability drivers

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Standard Signal to Noise Ratio Equations

$$S = R \cdot \Delta\lambda \cdot \frac{\lambda}{hc} \cdot A_o \cdot \Omega_d \cdot T_o \cdot T_i \cdot \eta$$

$$SNR = \frac{S}{\sqrt{N_{shot}^2 + N_{read}^2 + N_{quantizer}^2}}$$

Where:

S = Integrated sensor signal electrons

R = Spectral radiance $\left[\frac{mW}{cm^2 \cdot ster \cdot \mu m}\right]$

$\Delta\lambda$ = Bandwidth of spectral channel $[\mu m]$

$\frac{\lambda}{hc}$ = Number of photons per unit energy $\left[\frac{photons}{W \cdot sec}\right]$

A_o = Entrance aperture area $[cm^2]$

Ω_d = Pixel instantaneous solid angle [ster]

T_o = Optical transmission

T_i = Integration time [sec]

η = Quantum efficiency $\left[\frac{electrons}{photon}\right]$

Signal to Noise Ratio Spreadsheet

Required:

o Size the photodiode, CCD and dead space for each spectral channel.

o Determine the land integration time.

o Meet SNR requirements for the ocean and land (using specified typical radiances).

o Input radiance and SNR requirements, optical transmission, quantum efficiency, read noise, dark current, entrance aperture area, and pixel solid area.

Procedure:

o Use worst case land or ocean maximum radiances to size each spectral channel (ocean uses full integration time - land integration time is a variable).

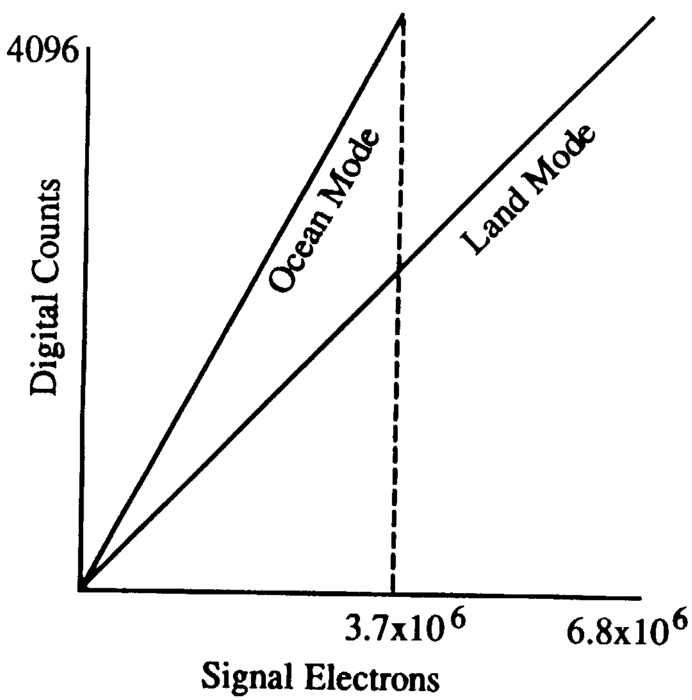
Photodiode width determines the spectral channel bandwidth.
CCD area determines electron full well capacity.

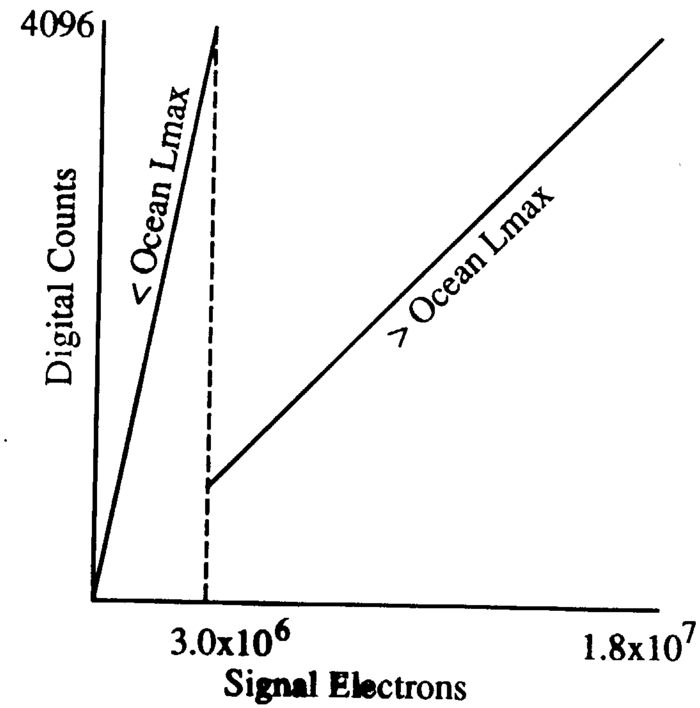
o Use land maximum radiances to determine land quantizer noise.

o Using the land typical radiances, vary the land integration time until the land SNR requirments are met in every band. First two steps are repeated for every integration time change.

o Use ocean maximum radiances to determine ocean quantizer noise.

o Calculate and plot the ocean and land SNR's.





Dual Mode - Two imaging modes: Land, Ocean
Ocean integration time - 1.13 ms
Land integration time - 0.30 ms
Ocean gain - 1.8 times land gain
Modes change on command
~ 14 nm bandwidths

Composite Mode - Single imaging mode
Single integration time - 1.13 ms
Ocean gain - 6.1 times land gain
Auto gain control
~ 11 nm bandwidths

Dual Mode (Present Baseline)

Advantages

Best Ocean SNR performance.

Ocean SNR performance can easily be maintained with degrated detector QE, detector charge well capacity or optical transmission.

Uses two 12 bit A/D converters (without redundancy).

Commandable fixed gain for land or ocean mode.

Disadvantages

Land and clouds saturate in ocean mode.

Two integration times.

Need to reset the photodiode at the end of every integration. Ocean needs to get rid of a saturated signal, land needs to get rid of the signal accumulated during the non-integrating time period.

Composite Mode

Advantages

No saturations.

Single integration time.

No photodiode reseting.

Improved land SNR performance.

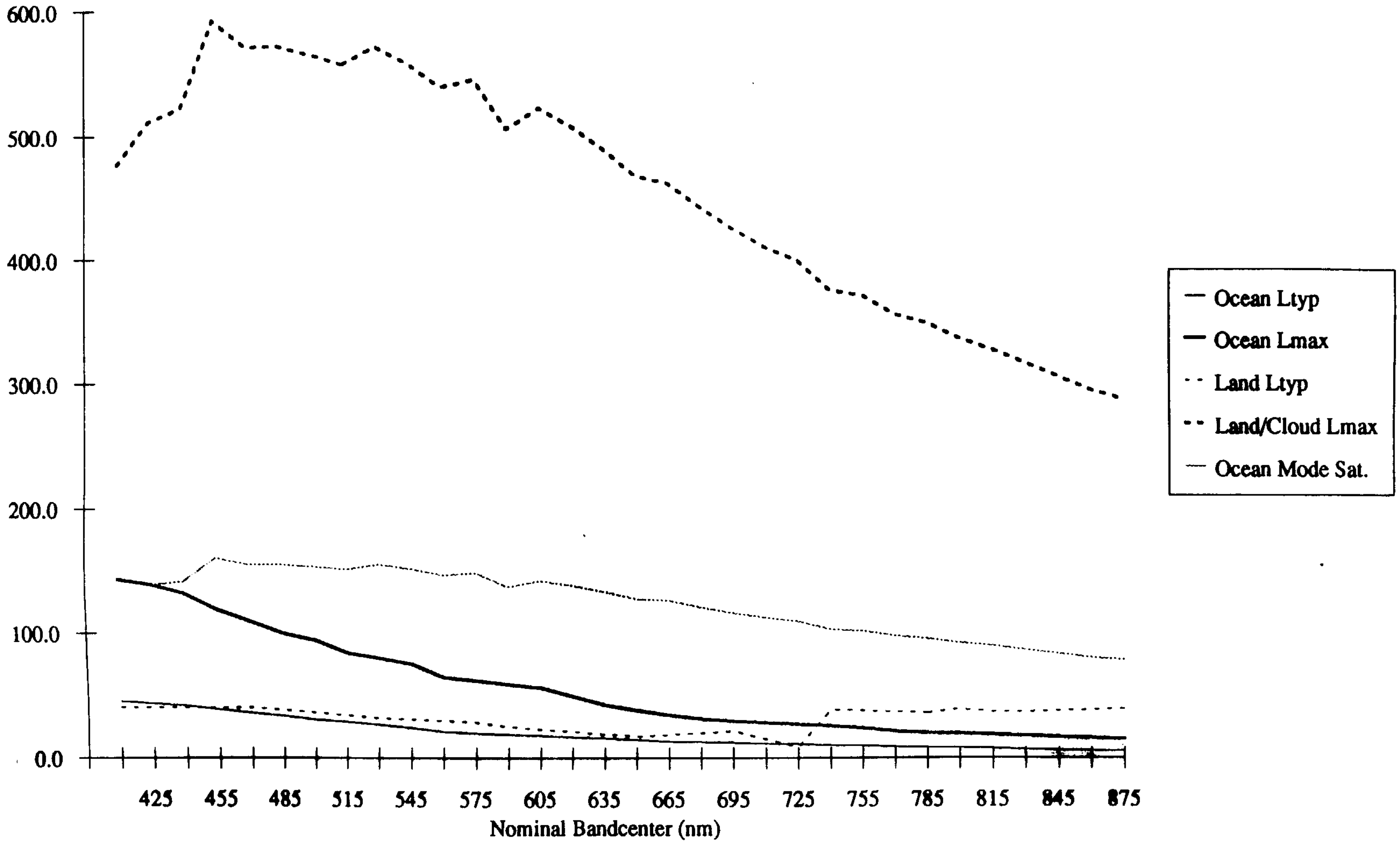
Disadvantages

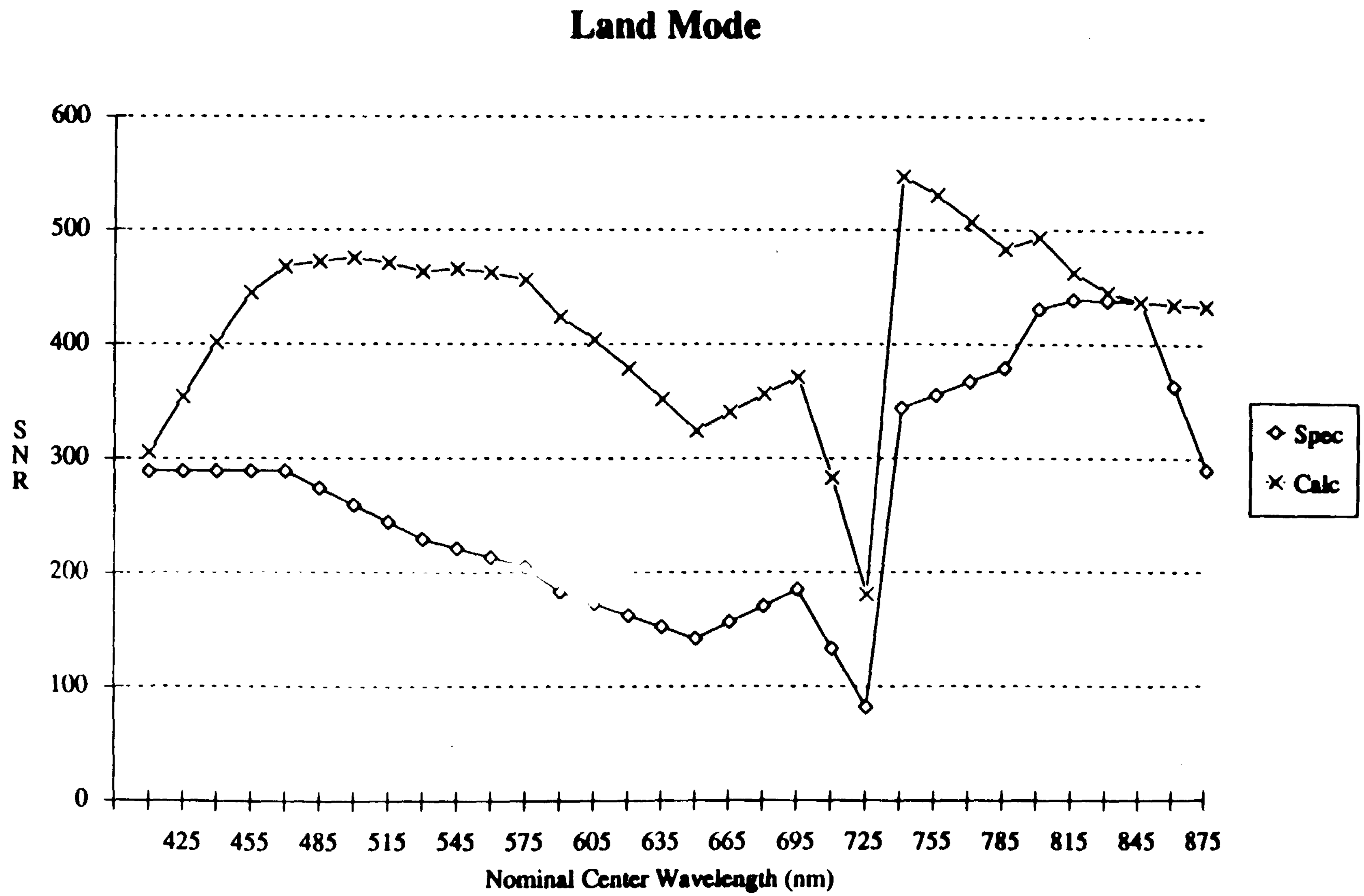
Need either four 12 bit A/D converters (without redundancy) or change gain on the fly with two A/D converters. Data rate will be 8.3% higher than dual mode.

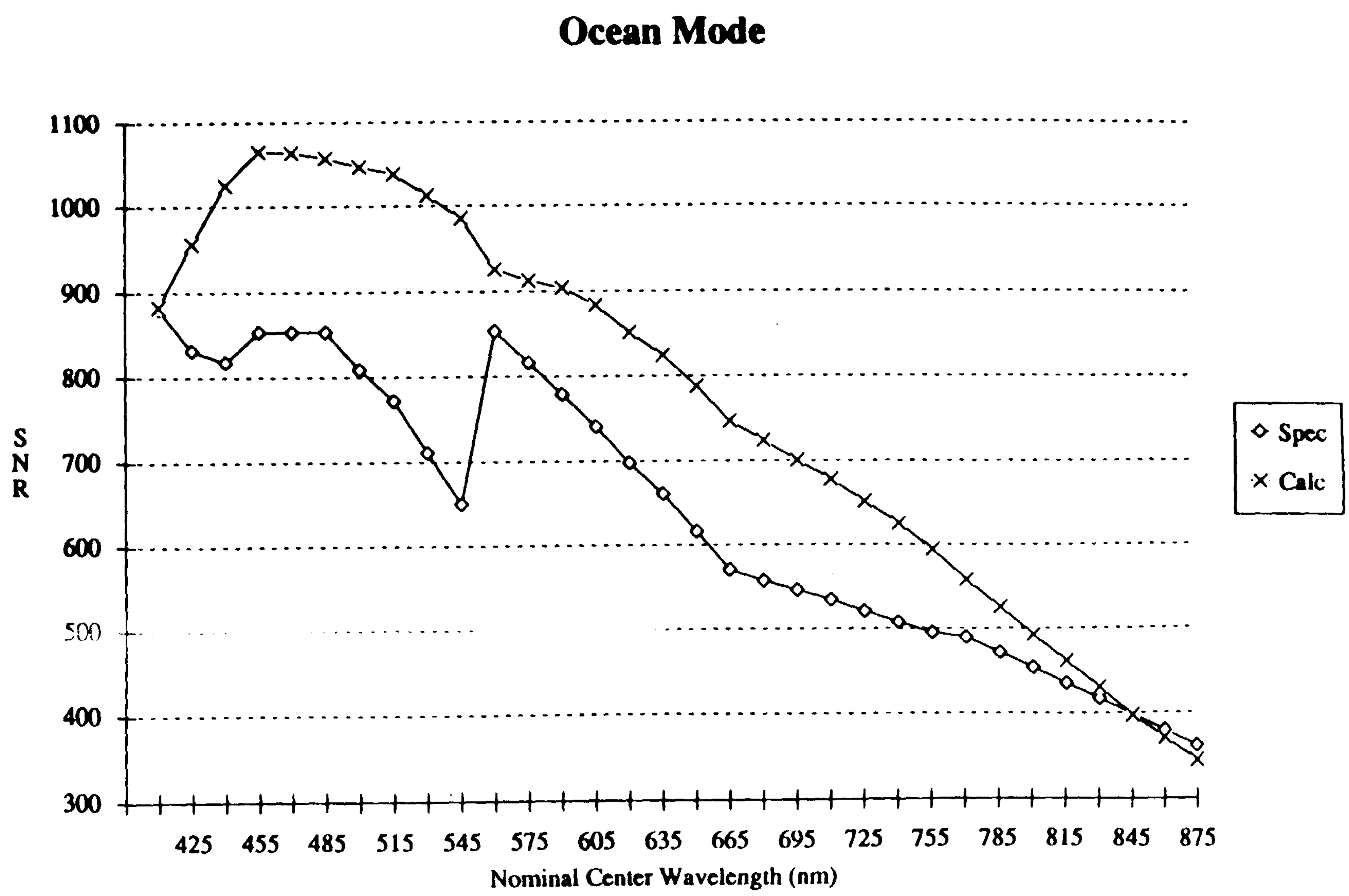
Degraded Ocean SNR performance.

Ocean SNR performance may not easily be maintained with degrated detector QE, detector charge well capacity or optical transmission.

Ocean/Land Radiances (W/m2*sr*µ)

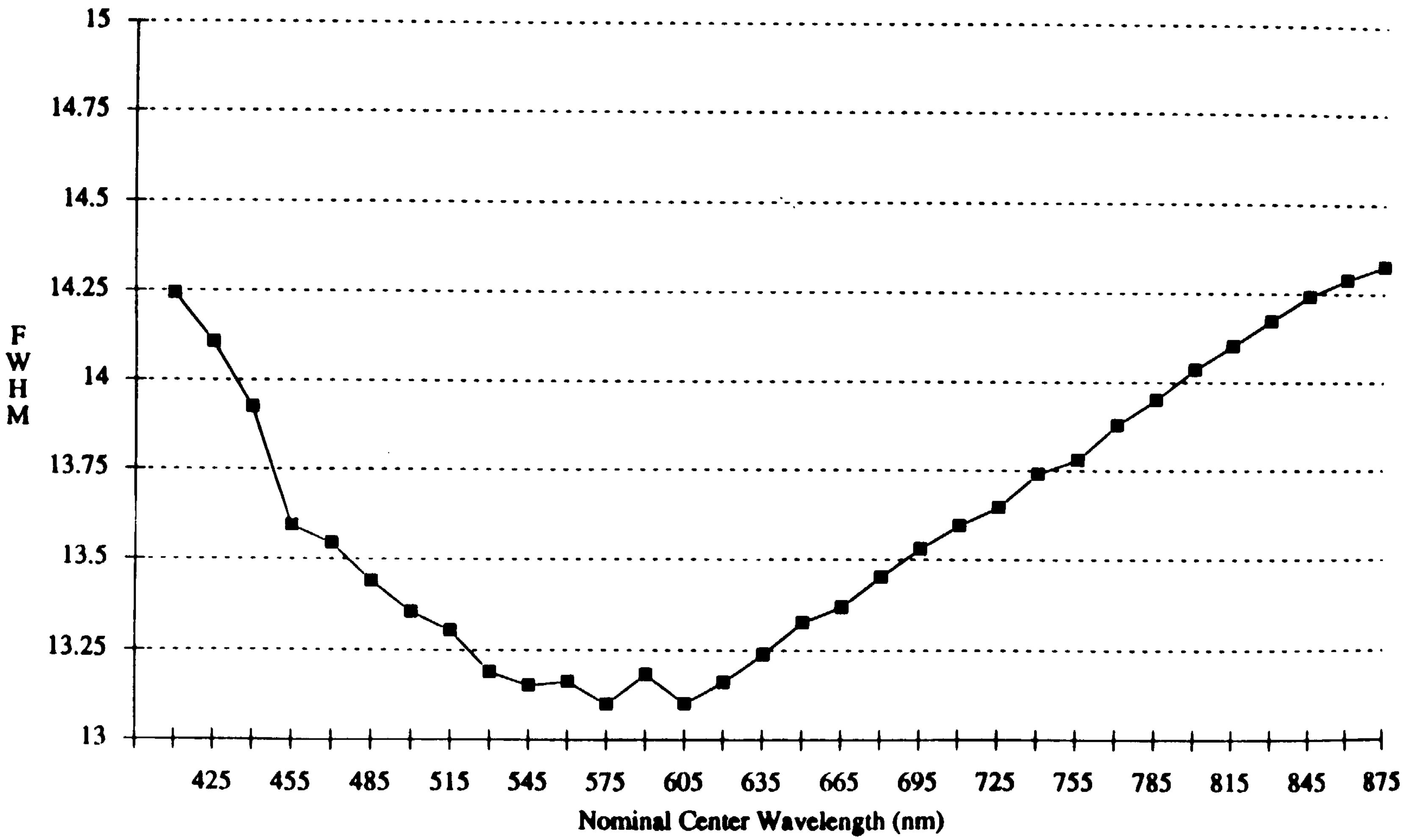



Land Mode
600
500
400
300
200
100
0
S
N
R
425 455 485 515 545 575 605 635 665 695 725 755 785 815 845 875
Nominal Center Wavelength (nm)
Spec
Calc

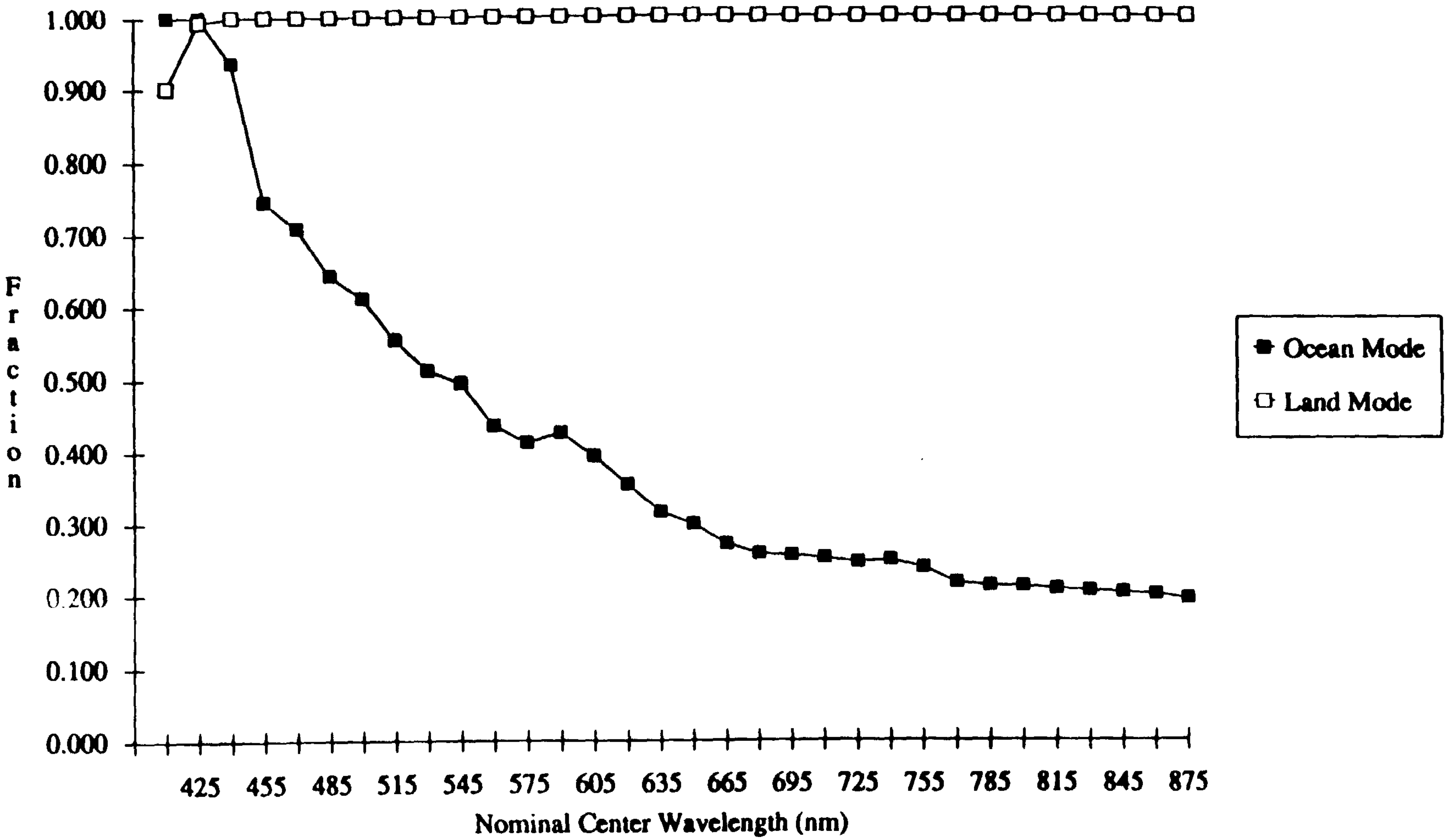


Ocean Mode
1100
1000
900
800
700
600
500
400
300
S N R
425 455 485 515 545 575 605 635 665 695 725 755 785 815 845 875
Nominal Center Wavelength (nm)
Spec
Calc

Bandwidth (FWHM)



Charge Well Utilization



Land Composite Mode